Comparative Analysis of the Properties of Diffusion Coatings

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Research Objective

Studying the possibility of applying DLC (Diamond-Like Carbon) coatings to strengthen parts of an internal combustion engine in a more effective way, which will allow achieving high wear resistance combined with impact and oxidation resistance.

Study Results

The valve gear assembly performance largely depends on its design: the camshaft position, the follower type, and the mass and rigidity of the parts. The modern engine valve gear assembly systems, various in type and design, experience significant loads, which account for up to 50 % of engine failures. These include the wear and tear of the valve faces and seats and the cam and follower's faces, the breakage of valve springs, the loss of stability and deformation of the rods, the sticking and breakage of the valves, and the change in the expansion gap. Pairs such as the cam-follower wear the most intensively (Fig. 1).

Fig. 1. The Cam Wear Types

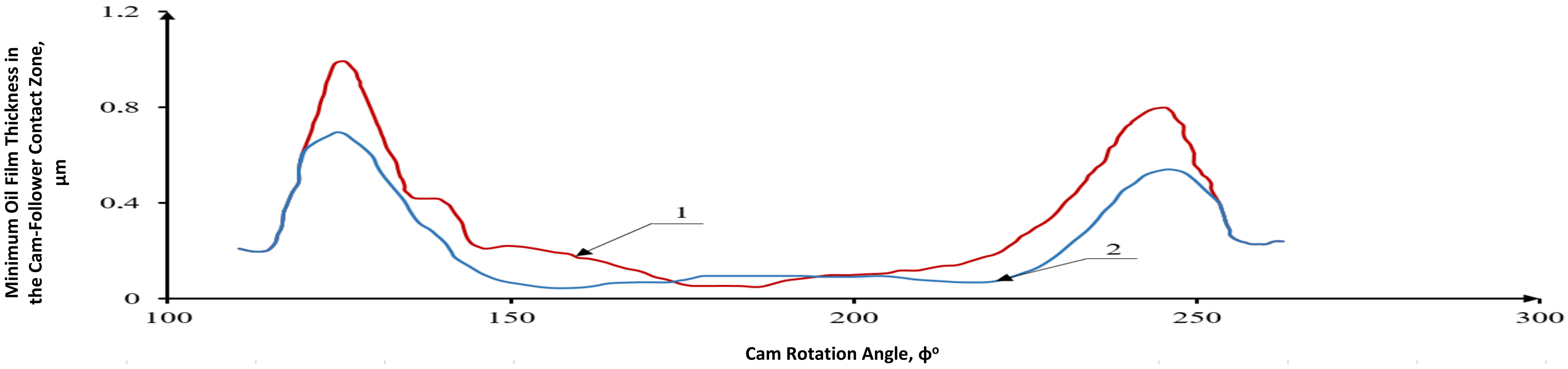

Fig. 2. The Minimum Oil Film Thickness in the Cam-Follower Contact Zone in the Cam Rotation Angle at a Rotation Frequency of 1,500 rpm: 1 - calculated; 2 - experimental

Figure 2 shows the dependence of the change in the oil film thickness in the cam-follower friction pair contact zone on the cam rotation angle at a rotation frequency of 1,500 rpm. Calculated and experimental data indicate an unsteady friction surface lubrication mode due to the displacement of oil from the friction surface zone as a result of an increase in pressure. This may be among the causes of the intensive wear of the friction pair faces.

Sliding of contacting friction surfaces leads to a sharp increase in temperature in the contact zone, which contributes to liquefaction, intensive oxidation, and squeezing of oil from the work zone. Studying the KAMAZ engine has established that at a camshaft rotation frequency of 500÷600 and 1,000 rpm, the temperature in the contact zone reaches 300÷350 and 350÷370 °C, respectively. An increase in the shaft rotation frequency up to 1,500 rpm leads to a sharp increase in temperature up to 460÷480 °C. When scores appear on the contact surfaces, the temperature in the contact zone reaches 600÷700 °C in the form of spikes. Such temperature effects in the cam and follower surface layers may cause certain structural transformations and soften the metal.

To modify the friction surfaces of various machine parts to increase the hardness, reduce the friction factor, and improve resistance to high-temperature oxidation, hard-alloy coatings based on nitrides, carbides, metal oxides, and carbon are used.

Table 1. The Wear-Resistant Coating Types and Properties

Coating Material / Material Properties	TiN	TiCN	AlTiCN	AlTiN	AlTiCN	AlTiCrN
	Titanium nitride	Titanium carbonitride	Aluminum-titanium carbonitride	Aluminum-titanium nitride	Aluminum-titanium carbonitride	Aluminum-titanium-chromium nitride
Microhardness HV 0.06	2,300±300	3,500±500	3,000±300	3,300±300	3,300±300	3,000±300
Steel friction factor	0.6	0.2	0.2	0.7	0.7	0.4
Coating thickness, µm	2-4	2-4	2-4	1-4	2-5	2-4
Maximum permissible temperature in the contact zone	500 °C	400 °C	800 °C	800 °C	800 °C	800 °C
Coating color	Gold	Gray-blue	Dark pink	Dark gray anthracite	Dark violet	Silver
Key characteristics	Standard commonly used biocompatible coating	High hardness, wear resistance, strength	High hardness and elasticity, low friction factor, high oxidation resistance	High hardness, very high oxidation resistance	High hardness, very high oxidation resistance	High hardness, low friction factor, good oxidation resistance

The electron cyclotron resonance plasma etching has shown the possibility of obtaining strain-stress behavior quite similar to that corresponding to the prior art without a chromium undercoat. It should also be noted that when using ion etching technology in the three-electrode system, lowering the pressure (plasma) provides improved properties. As a rule, in a two-electrode system, the ion etching technology itself cannot generate plasma pressures less than 0.5 Pa.

This etching technology allows reducing the argon pressure and creating a multilayer DLC coating without a chromium undercoat.

It is recommended to apply a DLC coating onto a metal surface in the following steps:

1. Etching of the part in microwave plasma,
2. Applying a WC-C layer of gradient composition by the physical vapor deposition in a magnetron.
3. Applying a DLC coating onto the WC-C layer using microwave plasma.

For the best gradient composition of the WC-C layer, a clean tungsten layer is first spattered, and then a layer is applied with a gradual increase in hydrocarbon consumption. The layer and the recommended DLC coating thicknesses should be within 0.3-10 and 1-20 μm, respectively.

Conclusions

1. The camshaft surface temperature in the cam-follower friction pair contact zone has been analyzed depending on its state and rotation frequency.

2. The possibility of applying a DLC coating for surface hardening of internal combustion engine parts has been shown.

3. The use of hard-alloy coatings based on nitrides, carbides, and carbonitrides to increase wear resistance, reduce friction factor, and improve resistance to high-temperature oxidation has been proposed and justified. This is achieved by applying a WC-C layer to the part surface, followed by applying a DLC coating by vacuum ion-plasma spattering. This allows obtaining a more effective layer than in the case of using a chromium coating as an adhesive layer.

Thank you!

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